EXTENSION OF ABALONE FISHERY RESEARCH TO INDUSTRY AND OTHERS BY USING INTERACTIVE EDUCATIONAL COMPUTER SOFTWARE

(FIRDC Project 89/8)

FINAL REPORT

to

FISHERIES RESEARCH AND DEVELOPMENT CORPORATION

by

SOUTH AUSTRALIAN DEPARTMENT OF FISHERIES

19 December 1991

SECTION 1 - PROJECT TITLE

EXTENSION OF ABALONE FISHERY RESEARCH TO INDUSTRY AND OTHERS BY USING INTERACTIVE EDUCATIONAL COMPUTER SOFTWARE

SECTION 2 - OBJECTIVES

The objectives of the **originally proposed project** were:

- To make recent advances in abalone research accessible to the Australian abalone industry;
- To improve management of abalone fisheries through increased knowledge and understanding
- To develop new techniques of applying the results of fisheries research.

FIRDC granted only a small proportion of the funds originally applied for.

A year later, after viewing a prototype, it granted supplementary funding:

- To complete the software that now exists in prototype form;
- To edit and produce a user manual from the existing draft;
- To design an educational computer based training package;
- To present the model at the 1st World Fisheries Congress.

A proposed "workshop tour to transfer the results to industry" was not funded.

SECTION 3 - RESULTS

3.1 General

The project has resulted in the production and distribution of the **AbaSim** software package, two copies of which accompany this report.

Appendix A, copied from the user manual, lists acknowledgements, shows the contents of the manual and describes how to use the package. The benefits offered by the software package are listed on the order form (Appendix B).

Additionally, a prototype of an educational computer based training package called **AbManager** has been produced in collaboration with Dr Rob Day of Melbourne University, who will trial it in 1992.

The World Fisheries Congress was postponed for a year due to the Gulf War. However **AbaSim** has been widely shown to North American and European fisheries scientists (see below).

3.2 Distribution

The **AbaSim** package was released in September 1991.

Following consultation with the South Australian Abalone Divers Association, it was decided that an effective way of distributing the package to the Australian abalone industry was to deliver six copies of the package to the abalone industry associations in various states. This has been achieved via state fisheries departments, each of which was requested to maintain one copy in their library.

Additional copies have been distributed to other Australian fisheries departments and training institutions. These organisations were encouraged to obtain additional copies for use in staff training and to assist in further distribution.

In August 1991, FIRDC agreed that the South Australian Department of Fisheries sell **AbaSim** commercially. FIRDC will receive 10% of the sale price. The decision will be reviewed after three years.

As part of an overseas trip in September 1991, the project leader, Dr Philip Sluczanowski, demonstrated **AbaSim** at the annual conferences of the American Fisheries Society, the UK Marine Conservation Society and ICES. He also showed it to key officers at FAO (Rome), UNESCO (Paris) and RRAG (London). A number of sales have resulted and discussions are being held with potential overseas agents and distributors.

AbaSim was purchased and used as part of an FAO training project in Fiji in November 1991.

3.3 Feedback

The response of everyone who has seen or used the package confirms that it meets the original objectives of the project.

Commercial and recreational fishers, conservationists, fisheries managers, science communicators, research managers and senior scientists have been particularly enthusiastic about the benefits of the technology for providing new insights into the behaviour of fisheries systems that must be managed based on limited information (see Appendix C). Beverton, Pope, Shepherd, Holden, Megrey, Edwards, Garcia, Troost and Griffith praised the model.

They see the main uses of such models as communicating key and difficult fisheries management concepts to non-specialists (e.g. sustainable development, growth and recruitment overfishing, time lags, age sampling, cycles, rehabilitation). A user has remarked that "It's a great little minister convincer "

Some scientists suggest that **AbaSim** is not as useful as it could be because:

- the user cannot change the model parameters and thereby examine sensitivity;

  (**AbaSim** was not intended to be a scientific tool.)

- the assumptions of the model are not clearly stated in the documentation;

  (The documentation was aimed at non-specialists. "Small print" and references are provided for those who seek them.)

- **AbaSim** gives the false impression that fisheries management is simpler than it is in reality. In particular, the model does not take account of random variation or environmental effects and it is difficult to communicate uncertainty.

  (The scope of the product had to be limited and a complicated model would have alienated many potential users. The ideal presenters of **AbaSim** are scientists who use it to communicate general principles and then qualify the model in relation to the real world.)

3.4 Future development

A list of possible improvements to the package has been compiled and is continually being updated in response to user feedback. The information would be incorporated into the specification of a future product, if feasible and justified.

During 1992, the SA Department of Fisheries will market **AbaSim**, seeking the best mixture of means of distribution (e.g. mail order, agents, distributors, publishers). The marketing project will be reviewed at the end of 1992 and decisions made regarding further distribution, future product development and the feasibility of the department commercialising such products.

A supplementary grant may be sought to support the trialing, refinement of the prototype and specification of the **AbManager** package.

APPENDICES

A Acknowledgements, Contents of manual, Use of package

Copied from the AbaSim user manual.

B AbaSim order form

C "Flying Fisheries"

Article for American Fisheries Society Computer Users Section newsletter.

Warning

Published by the South Australian
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AbaSim: A Graphic Fishery
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John Tonkin, a computer artist, programmed the computer game.

We thank for their assistance, support and inspiration:

Abalone divers, their families and representatives
Garis Alexander, Alan Armstrong, Janine Baker, Kevin Branden, Tracy Brothers, Barry Burr, Merle Cammiss, Steven Clarke, Rob Day, Lesley Fairbairn, Ludmilla Filadelfi, Shaun Forbes, Wesley Ford, Ray Hilborn, Patrick Hone, John Jefferson, John Johnson, Ian Kirkegaard, Neil Klaer, Gordon Kuckhahn, Rob Lewis, Vivienne Mawson, Carol Moore, John Nowland, Mick Olsen, Sharon Palmer, Russ Reichelt, Natalie Schenk, Scoresby Shepherd, Hosi Stankovic, Simon Talbot, Richard Tilzey, Angelo Tsolos, Mike Walker, Carl Walters, Meryl Williams, Gavin Wright, Marko Zagar

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Tasmanian Fisheries Development Authority: research

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Fishing Industry Research Trust Account: research

Contents

APPENDIX A
- Acknowledgements
- Contents of Manual
- Use of Package

Start here

About this manual

Usually when people buy a new computer game, they cannot wait to try it. But before you use **AbaSim**, please *Resist this temptation!*

Read the first three chapters of this manual first, and then play the games described in chapter 4. You will learn about abalone and fisheries management, and be entertained on the way.

The **AbaSim** program and manual were designed for a wide audience. We do not assume you know anything about abalone or about personal computers (PC's). But you will need to have access to a computer compatible with an **IBM-PC 286** with a **colour VGA screen**, preferably with a maths coprocessor.

AbaSim simulates what happens to a population of blacklip abalone, *Haliotis rubra,* on a reef when it is fished by abalone divers. The model uses information about the growth, reproduction, mortality and movement patterns of abalone and the behaviour of divers. It represents scientists' understanding of the dynamics of a fishery based on the abalone that live on a small reef off Tasmania. The fishery based on this stock was studied as part of a major research program carried out in Australia between 1984 and 1987, led by Dr Jeremy Prince.

Chapters 1, 2 and 3 introduce you to abalone biology, abalone divers and fisheries management. If you want more details about the models and their relationship to research results, consult "the small print" in Appendix B, the references (Appendix C) or write to the authors. Scientists are still investigating many of the issues discussed.

Chapter 4 **(Games)** is the most important in the manual. Use it to discover the dynamics of AbaSim Reef while "playing". Use this chapter to learn how to use the simulator. Don't cheat, or you'll miss some surprises. Chapter 5 discusses useful lessons about fisheries that arise from Chapter 4.

Chapter 6 tells you how to install the software and operate the program. It explains how information is shown on the computer screen. Use this chapter for reference.

When you use **AbaSim**, try to forget you are sitting in an office with a

computer. Instead, free your imagination; you are a god playing with the world! Well, not quite, but you are the manager of a fishery. And your computer is a terminal which reports what is happening in the world.

When using **AbaSim**, keep asking the question: "What happens if...?" and use the model to find out. Before making the model simulate a situation, try to predict what will happen and why. The gap between your expectation and what happens will stimulate you to think further and generate greater understanding and insight.

Good fisheries biologists learn about a fishery by applying scientific research techniques, studying the results and talking and working with fishers and other observers of the stocks. They then build a picture, or mental model, of how the fishery works. Most fishers do the same. Both use these mental models to help them understand and predict what will happen in the fishery: the fishers to help them catch fish effectively, and the biologists to manage the fishery better. A model is a purposeful representation of reality.

When you stop using the simulator, remind yourself that the **AbaSim** model is just a model and not an exact duplicate of the real world. It represents some of what we currently believe about abalone fisheries; it is not an actual abalone stock. It is limited by the extent and accuracy of research to date, our overall understanding and what is feasible to model. Models such as **AbaSim** are useful for developing understanding, but not necessarily for making accurate predictions about the real world. The purpose of this model is to gain insights and to find out where our understanding about the real world is weak and should be improved.

The successful management of fisheries is vital not only to the people whose livelihood depends on them, but also to a world of dwindling natural resources. Fisheries managers are at the forefront of learning how living resources can be developed in a sustainable way. **AbaSim** is designed to help managers understand how fisheries behave – and how managers' actions can affect them.

Enjoy using **AbaSim**. Please don't spoil the game for others by showing them what they should discover for themselves. Your suggestions for improvements are welcome.

Philip Sluczanowski, *Producer*

30 August 1991

APPENDIX B

AbaSim Order Form

AbaSim

FISH INSIGHT

"Faaaaantastic. he games are very easy to 'play', tructions are easy learn and apply, ions few and easy get used to. The reen is brilliant."
Carol Moore
Senior Computer
Systems Officer

is program comes ser than anything lse I have seen to revealing how alone populations behave. It is evolutionary and exciting."
oresby Shepherd,
Biologist

A GRAPHIC FISHERY: Learning tool for fisheries management

The **AbaSim** computer program simulates a fishery based on a shellfish population that lives on AbaSim Reef.

Try being its manager. Your aim is to preserve the fish stock and develop it sustainably. While "playing" the easy-to-use computer program, you will learn important principles of fisheries management, and be entertained at the same time.

AbaSim simulates what happens to a population of abalone when it is fished by abalone divers. Each year, you can change the minimum size limit and adjust the fishing pressure. The catch and profitability of abalone divers harvesting the reef respond to your controls. You immediately see the effects as coloured dynamic graphics easily understood by non-specialists. You can also carry out research surveys. The model uses information about growth, reproduction, mortality, movement patterns and diver behaviour. It is based on real data.

The **AbaSim** program and manual were designed for a wide audience. To use it, you do not need computer experience or knowledge about fisheries or abalone.

The manual tells you about abalone biology, fisheries management, and the Australian fishery on which the model is based. An "easy-going" commentary leads you through scenarios, relates them to real world experiences, and leaves you to manage the fishery on your own. Later, it explains what happened and why, and draws lessons relevant to the real world.

The Australian Fishing Industry Research and Development Trust Fund (FIRDTF) supported the development of **AbaSim** and benefits from its distribution.

AbaSim should be considered a cost-effective and time saving method of improving the performance and understanding of participants in the fisheries management process.

HERIES MANAGERS

- The successful management of fisheries is vital not only to the people whose livelihood depends on them, but also to a world of dwindling natural resources. Fisheries managers are at the forefront of learning how living resources can be developed in a sustainable way. AbaSim is designed to help managers understand how fisheries behave - and how managers' actions can affect them.

FISHING INDUSTRY

- Continued and profitable harvesting of natural resources requires an understanding of the dynamics of the fish stock, a commercial fishery's core asset. This requires knowledge of biology and of population dynamics. **AbaSim** teaches these subjects simply.

ONSERVATIONISTS

- It is important that the public appreciates what is meant by sustainable management. Then they can respond when non-sustainable practices occur.

  AbaSim can convey an understanding of the basic issues to a wide audience. The user can demonstrate alternative sustainable fishing policies and compare their benefits.

FISHERIES DEPARTMENTS

- Staff of a fisheries department appreciate the relevance of their work better if they understand the basics of fisheries management. **AbaSim** has been trialed as a training tool to achieve this. Managers, enforcement officers, administrators, communicators and scientists all found the experience instructional and satisfying.

  A person training with AbaSim needs about 2-4 hours alone with a computer.

SCIENCE COMMUNICATORS

- The model illustrates types of behaviour often experienced by species other than abalone. **AbaSim** can be easily used to demonstrate some of these (e.g. sustainable development, overexploitation, time lags, eradication of a stock's spawning potential, age sampling, cycles, rehabilitation, etc.).

  You can also use **AbaSim** to illustrate analogies in wildlife and other areas of natural resources management.

EDUCATORS AND STUDENTS

• **AbaSim** is an educational tool. The manual describes the latest knowledge about abalone biology and fisheries management. Key references are listed.

The model is suitable for university tutorial sessions, during which students can either follow the book's scenarios or be asked to experiment with the model and thereby gain insights based on their experiences. It has relevance in a wide range of subjects, e.g. biology, environmental studies and resource economics, mathematics, communications design and graphics design.

Schoolteachers can easily use the model to demonstrate some fundamental lessons about the behaviour of fisheries. 10-year olds can easily understand the screens and "play the game" after a few minutes' tuition.

ERIES SCIENTISTS

• **AbaSim** offers a completely new view of the dynamics of an exploited fish stock. Dynamic visualisation and interactive graphics techniques reveal what is happening to the population structure when you manage the stock in different ways.

You use **AbaSim** like a flight simulator, gaining a feeling for the sensitivity of the dynamics and insights into the behaviour of the nonlinear system. The screen displays offer new visualisations of complex relationships previously only accessible through numbers and equations.

(Unfortunately, you cannot change the underlying model parameters.)

OMPUTER ARTISTS

• John Tonkin, who designed and programmed the screens, is an award winning Australian computer artist. **AbaSim** is an example of how artists can apply their unique communications skills.

certainly learn a fair bit of how a iery can collapse l how it can also ıved. Sometimes ear is all it takes save the fishery."
Angelo Tsolos
Senior Statistics
Clerk

I think that as a teaching aid for oducing students he broader range of fisheries ınagement issues the model is unsurpassed."
Don Mackie, past
orcement Officer

Computer hardware required: • IBM-PC.286 compatible • colour VGA screen
• maths coprocessor (optional, increases speed)

Developed by: FISH INSIGHT

Contact: FISH INSIGHT, South Australian Department of Fisheries, GPO Box 1625, Adelaide, SA 5001, Australia

Customer Hotline: For details or a quotation on FISH INSIGHT services and products, please write to us. Or call our Customer Hotline in Australia Telephone 08) 226 0633 Int ...) 618) 226 0633 Facsimile 08) 226 0664 Int ...) 618) 226 0664

To order your copy of **AbaSim**, please complete and send or fax this order form to FISH INSIGHT

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Delivery: Allow 21 days. Customs duty: We'll make every effort to ensure your copies of **AbaSim** reach you quickly and take every care to protect you from customs duty. However, we cannot

1/91

APPENDIX C

Article for American Fisheries Society Computer Users Section Newsletter

FLYING FISHERIES

Pilots and fisheries managers both have to control complex dynamic systems in fluctuating environments. The better they understand the behaviour of the systems they are trying to manage (i.e. aeroplane or fishery), the more effective they are.

Scientists and engineers usually lead the development of understanding through research, experimentation and design. But is this level of understanding sufficient, and how best to communicate it ?

An aeroplane designer is familiar with the equations and performance levels describing a plane's behaviour and can explain the likely consequences of using different controls under various conditions. But can he (she) fly a plane ?

Certainly not, based on this "theoretical" level of understanding. To fly a plane, a pilot needs to experiment with the system to gain a "feeling" for its dynamics, sensitivity and responsiveness. The only way to do this is to interact with it through an effective user interface. This could be either a flight simulator or the aeroplane itself.

Interactive graphics models of fisheries offer similar advantages. You can combine the equations describing a fishery into a computer program which simulates certain aspects of a its behaviour. You can then outfit this model with a user interface that allows the user to easily interact with it and immediately see the consequences of different management actions. The user can "fly" the system and so learn about it.

FISH INSIGHT, a unit of the South Australian Department of Fisheries, specialises in providing a high quality user interface for models developed by others. The interactive graphics interface makes the models easily accessible, provides new insights into their complex dynamics and allows communication of this understanding to non-specialists.

AbaSim is one such program. It simulates what happens to a population of abalone when it is fished by divers. As the user, you act as the manager of the fishery. Each year, you can change the minimum size limit and adjust the fishing pressure. The catch and profitability of abalone divers harvesting the reef respond to your controls.

You immediately see the effects on the population as coloured dynamic graphics easily understood by non-specialists. The model is based on real data and uses information about growth, reproduction, mortality, movement patterns and diver behaviour.

Although **AbaSim** is based on an abalone population, it illustrates types of behaviour experienced by species other than shellfish. For example, it is easy to demonstrate "sustainable development", "growth overfishing", "recruitment overfishing", "the value of age sampling", "cyclic behaviour", "rehabilitation of a fish stock", etc.

SharkSim is another interactive graphics model. It is based on Australia's southern shark fishery. Commissioned as "an agent for change", it was used by scientists and managers in public meetings to convince industry and the public of the need for urgent and significant changes to management of the fishery. It did so by effectively communicating scientists' best understanding of the state of the stock and the likely consequences of alternative management actions.

Scientific visualisation and interactive games are rapidly growing areas of science made possible by recent advances in computer technology. They will change the ways in which we view data and analyse relationships.

Dr. Philip Sluczanowski

FISH INSIGHT

South Australian Department of Fisheries
135 Pirie Street, Adelaide, South Australia.

Postal address:
GPO Box 1625, Adelaide, SA 5001, Australia.

Telephone: ...61) 8) 226 0633
Facsimile: ...61) 8) 226 0664

FISH INSIGHT

South Australian
Department of Fisheries

AbaSim

A Graphic Fishery

Jeremy D Prince
Philip R Sluczanowski
John Tonkin

AbaSim

Warning

Unauthorised copying of
the **AbaSim** software or manual
is unethical and illegal

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Fishing Industry Research and Development
Trust Fund

The authors

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Authority: research

Tasmanian Abalone Divers Research &
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Fishing Industry Research Trust Account:
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Enjoy using **AbaSim**. Please don’t spoil the game for others by showing them what they should discover for themselves. Your suggestions for improvements are welcome.

Philip Sluczanowski, *Producer*

30 August 1991

1 Abalone biology

This chapter describes the world being simulated by the **AbaSim** computer model. It relates what is known about the abalone population on George III Rock and presents a mental picture of the reef with which you will be "playing".

In many ways, this population of abalone is like any other in the world. However the model is specific to a reef in Southern Australia and it also takes no account of environmental or random effects. These have to be accepted as limitations.

Location and habitat
George III Rock is about 2 kilometres offshore in south eastern Tasmania (43°31'S, 146°58'E.). The rock was named after wrecking a ship transporting convicts in 1834. It was nominated by local abalone divers as a good research site because it is typical of the commercial abalone beds in the area.

George III Rock is actually a reef about one kilometre square, with the rock from which it takes its name in the centre. This rock is surrounded by bedrock covered by several layers of boulders. Outside the central area, in depths of 10-18 m, the bottom is less complex and scattered boulders sit on the exposed bedrock or on sand. The sea breaks regularly over the rock. The reef is surrounded by sand. The nearest reefs are two or three km away.

String kelp, *Macrocystis pyrifera,* grows on the reef below 11 m depth, while bull kelp, *Durvillaea potatorum,* grows in the shallower areas.

In the computer simulation model, the reef has been renamed "AbaSim Reef" and is a square made up of 25 cells, each 100 x 100 m. The central cell is the shallowest area of the reef and the outermost cells are the deepest (Figure 1).

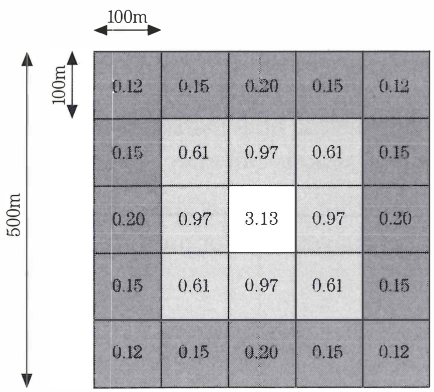
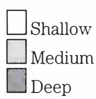


Figure 1. Typical density pattern (abalone per square metre) produced on Abasim Reef by the model.



Ages and growth

Abalone are long-lived marine snails. Even in an exploited populations it is often possible to find individuals that are more than 20 years old (see Appendix B.1).

Abalone grow most rapidly when they are young and immature. Growth continues after they mature, but slows down because they put more of their energy into breeding. Figure 2 shows the weight of individual abalone at different ages measured in the field and used in the model.

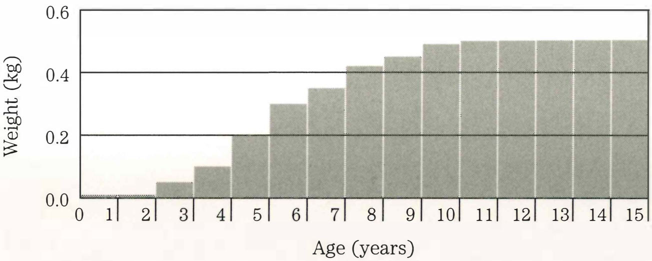


Figure 2. Growth: weight of an abalone at various ages (AbaSim Reef).

Mortality

The abalones' main defences against a hungry world are their thick shell and their strong grip on rocks. As the young ones have not developed these, they are extremely vulnerable to predators, which is probably why they hide amongst the boulders of the reef. As they grow larger and their shells strengthen, they move onto more exposed rocks where they can be found more easily by divers. Figure 3 shows that their natural mortality rate declines with age (Appendix B.2).

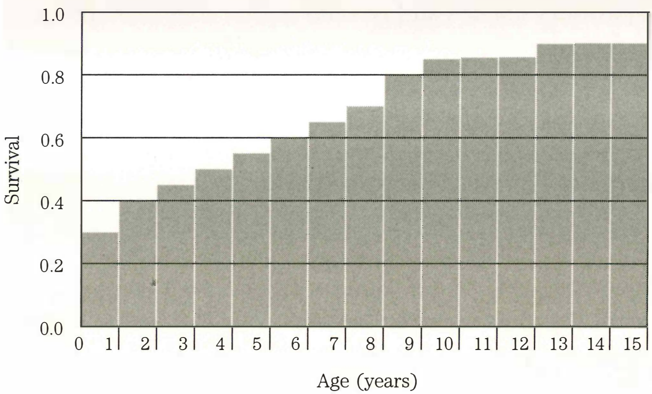


Figure 3. Proportion of abalone of each age surviving to the following year in an unfished population (AbaSim Reef).

Recruitment to the fishery

Blacklip abalone in Tasmania mature between the ages of 5 and 12 years. About half of the population is mature by 7 or 8 years. When they reach maturity the abalone move out into the open where they become vulnerable to divers. In fisheries terms they become "recruits to the fished population".

In the model all the abalone mature and recruit to the fishery when they are 7 years old.

Movement patterns

The abalone at George III Rock had two patterns of movement.

The first was random shuffling, apparently related to feeding. Abalone are vegetarians. In Australia they seem to prefer small, fleshy red seaweeds, which they will actively search for and graze on. They will also catch bits of broken seaweed drifting past.

If a group of abalone were placed in one of the 100 x 100 m cells that make up AbaSim Reef, this type of movement would lead them to spread over time throughout all 25 cells. Research has shown that there is more movement when there is not much food. In the model, the amount of food in any cell depends on how many abalone are there (Appendix B.3).

The second type of movement is directional and may be related to abalones' breeding or feeding behaviour. Some populations apparently move towards the oncoming swells, others form aggregations along the sandy edges of reefs, (possibly because currents concentrate food supplies there), and still others move towards shallower depths.

Reproduction

Abalone are "broadcast spawners". Males and females gather together and at some signal start releasing eggs and sperm into the water. The eggs mix with the sperm in the water and are fertilised. The eggs hatch into larvae. This process is most likely to be successful if the aggregations at breeding time are large. Possibly, the directional movement described above plays a part in forming these aggregations.

On AbaSim Reef, in the simulation model, abalone are assumed to be more likely to move towards the shallow water than deeper water (Appendix C.4), so they aggregate in the central cell of the reef. Figure 1 shows a typical stock density pattern (abalone per square metre) produced by the model. It is very similar to that observed on George III Rock, where 50% of the abalone were found to be clumped in only 14% of the reef area.

To date no one has shown that the number of adult abalone in an area determines the number of young abalone that grow up there. In scientific language, no one has proved (or disproved) that there is a relationship between the size of the breeding stock and the number of animals that subsequently recruit to the fishery.

On AbaSim Reef, we avoid this difficulty by specifying that the number of young abalone is related to the number of adults. This relationship is shown in Figure 4, where a density of about 1.7 abalone per square metre produces the greatest number of one-year-olds at the start of the following year. Above this level the number declines (Appendix B.5).

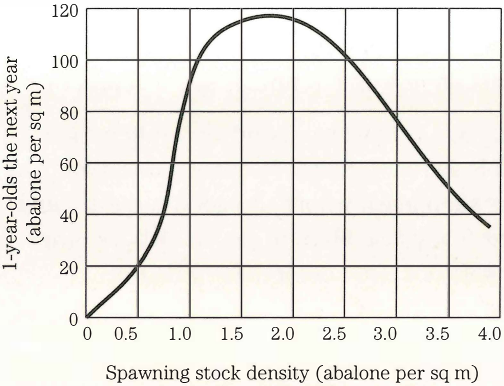


Figure 4. Reproduction: how spawning stock determines the number of one-year-olds produced at the start of the following year (AbaSim Reef).

It used to be thought that abalone larvae could be carried long distances from their parents and could settle onto reefs many kilometres from where they were spawned. However, recent research on blacklip abalone suggests that most of the larvae that settle successfully remain very close to the area in which they were spawned (Appendix B.6).

2 Abalone divers

A fisheries biologist must be a student of human nature as well as of aquatic nature. Describing how an abalone lives, moves, dies and reproduces is only half of the story; the other half is the diver who catches them. We must also describe how an abalone diver behaves if we want to be able to simulate an abalone fishery.

All fishers must decide where they should start fishing each day. Most fishers (those who aren't abalone divers) will try a spot to see if it's going to be worth fishing. After a while they wonder if they can do better elsewhere, and decide whether to move. It normally takes some time to work out where they'll do best for the day. Fisheries biologists call this 'searching time'. A fisher's catch rate at the end of each day will depend in part on how much time is spent searching.

An experienced abalone diver arriving at a reef won't spend very much time searching; he or she will quickly be able to tell if the reef is a good one simply by looking at the bottom. Abalone divers soon learn where the good reefs are and where the abalone aggregate on them. They also learn to predict where other concentrations might be on reefs they've not tried before. They do not, therefore, have long "searching times".

But abalone divers must also take into account such matters as rough water, strong currents, poor visibility and depth. These will affect their decision as to where to dive. Abalone divers asked to fish down the abalone population on George III Rock fished the shallow water areas harder than the deeper areas (Appendix B.7).

> For the simulation model we assume that divers spend so little time searching in their boat that we can ignore it. All they do is anchor over the spot they've chosen and jump into the water to start collecting abalone. In the simulation model, divers allocate their effort directly to the most preferred cell. Their preference for each cell is based on the number of abalone in it and its depth. Their preference for shallower cells creates differences in the catch rates similar to those observed during experiments at George III Rock.

When abalone divers "jump on a spot" and start swimming around, their catch rate (or 'catch per unit effort' or CPUE) will be determined by how fast they can cover an area of bottom and how quickly they can find and 'chip clunkers' (i.e. catch abalone) off the rock and put them into their net bags.

Research conducted on George III Rock found that divers covered an average of 1,128 square metres of reef each hour with 100% efficiency (Appendix B.8). A study in Victoria found that the average diver took 5.1 seconds to handle each abalone (Appendix B.9).

Figure 5 shows how a diver's catch rate, and therefore his or her profitability, depends on the different densities of abalone he or she finds.

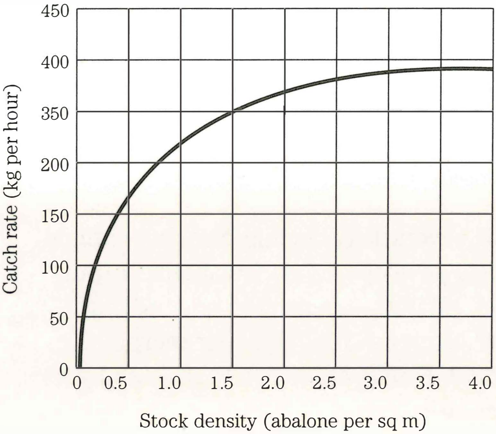


Figure 5. How catch rate CPUE depends on stock density (AbaSim Reef).

3 Fisheries management

Until the Second World War little attempt was made to manage fisheries. It was believed that market forces would manage renewable resources. The theory was that as an overexploited fish stock declined, the fishery would become unprofitable and fishers would leave the fishery, giving the fish stock a chance to recover. Management measures such as size limits or seasonal closures were used for economic rather than conservation purposes; for example to make sure the catch was the best size or in the best condition for the market.

During the 1950s and 1960s it was discovered that market forces could destroy fish stocks. Managers began to realise that fishers with fully depreciated fishing gear could economically fish stocks to commercial extinction and keep them there.

If a stock is fished too hard, catches will eventually decline. Seeking optimal levels of exploitation, fisheries scientists developed theories about "surplus yield" and "maximum sustainable yield". Many concentrated on studying growth and mortality. The results were often used in "yield per recruit" analysis, which determines how the yield of an average fish is affected by its size at first capture and by fishing pressure.

Despite the complex mathematical models that have been applied to analysing fish populations recently, uncertainty and risk still dominate fisheries stock assessments – and consequently the advice scientists provide to managers.

3.1 Stock indicators

Even harder than developing theoretical models of fisheries is trying to find out what is actually happening underwater. Scientists have enough trouble measuring things that stay still on the land – such as trees – let alone animals that roam around at the bottom of the sea.

The first approach to measuring fish stocks is direct. Scientists go out and count fish. But surveys are slow and expensive. And it is only possible to measure one small part of any fish stock; how to relate the results to the total stock is a constant problem.

> We avoid this difficulty at AbaSim Reef, where the survey data shown on the screen are very accurate. If you conduct a research survey in any year you will see exactly how many abalone of each age class were on the reef at the end of the previous year. You can decide for yourself what it means.

The second approach to monitoring fish stocks is less direct: the researcher collects the fishers' catch and effort records, which is a relatively simple and cheap exercise.

This approach is based on the assumption that the catch rate (or CPUE) reflects the size of the stock. It seems logical that if fishing has reduced the number of fish in a stock by half you should expect CPUE to be halved. Many fish stocks are monitored on this principle.

AbaSim shows you catch and CPUE information that you can use to help you monitor the simulated abalone stock.

3.2 Fisheries management tools

Generally, fishery managers use four main tools to control exploitation:

1. Protect part of the fish stock by imposing minimum size limits (to ensure only the older fish are caught).

   In **AbaSim**, we implement this control by setting a minimum **Age** at which abalone can be caught.

2. Limit how hard fishers work. We call this **Effort** control mode.

3. Limit the size of the catch, which is called **Quota** control mode.

4. Close some areas to the fishery. (This mode is not used in **AbaSim** because AbaSim Reef is too small.)

The abalone at AbaSim Reef can't be caught before they are 7 years old because they are hidden under boulders and divers usually do not carry crowbars. However, you can change this **Age** anywhere between 7 and 15 years. The model uses an age limit rather than a size limit, as would happen in practice, because we assume that all the abalone on the reef grow at the same rate. You should remember that the abalone on AbaSim Reef breed at age 7, so if you allow the divers to fish hard with a low size limit they could fish out virtually all the breeding abalone.

Fishing effort can be limited by restricting the number of fishers, shortening the fishing season or preventing them from using more efficient gear. The main difficulty with these methods is that fishers are very clever at finding ways of working harder or becoming more efficient. You don't have this problem at AbaSim Reef. If you set a level of **Effort**, divers will keep to it.

When you implement a quota system in the real world you must decide how to allocate it between fishers. You don't have this problem at AbaSim Reef. Simply select **Quota** mode, choose a level of quota, and the computer will keep the divers happy.

In summary, when playing **AbaSim** you can easily control three management tools by using the keyboard:

1 **Age** at first capture
2 Fishing **Effort**
3 Catch **Quota**

3.3 Managing a fishery

Now you know how to adjust the three management controls. So how do you manage a fishery? How much fishing effort should you set? What size of quota? How much stock should be left in the water? How should you adjust your decisions in the light of the stock indicators you are monitoring?

In theory, the answer is simple: you must leave enough abalone in the water to produce the maximum sustainable yield for AbaSim Reef. To achieve this, fisheries biologists have several rules of thumb (some of which have been likened to "vaguely stated wisdoms of witchcraft").

In the past, most fishery managers tried to proceed with caution, controlling the expansion of the fishery if they could and watching the stock indicators for signs of trouble. (i.e. They adopted a cautious "suck it and see" approach.)

Professor Carl Walters (1986) argues that this approach has led to the collapse of many fisheries and, moreover, the cautious approach will have prevented us from learning about the stock in the meantime. He proposes a new approach called Adaptive Management. He argues that wherever possible, fisheries should be divided into parts and managed experimentally. Different management techniques should be deliberately applied, ranging from complete protection to very heavy exploitation. Then, if parts of the fishery decline, the managers will at least be able to compare those sections and the techniques used to manage them with the remaining productive areas and learn from the comparison. Walters argues that when a fishery managed as a unit declines, all that is learnt is that the fishery should have been managed differently.

Now, you know:

Why you should manage the abalone fishery of AbaSim Reef (it will probably collapse if you don't)
How to monitor the state of the stock (research surveys and CPUE)
What management techniques you can apply (Age limits, Effort and Quota).

Your career as a fisheries manager is about to begin.

4 Games

This chapter has been written to entertain and teach you. In it, you will be introduced to **AbaSim** and to the art of simulation. We shall lead you step by step through some scenarios ("games") and at the same time teach you how to use the simulator. We suggest that you work through this chapter carefully and thoroughly.

Use this chapter to learn how to use the simulator. Use Chapter 6 for reference.

The three exercise games provided with the software have been chosen because they are typical of what has happened within the Australian industry and each highlights certain interesting features of abalone fisheries. In chapter 5 we discuss some of the points raised by these scenarios in more detail.

You will gain more from the simulation model if you let your imagination run free, and imagine that the computer is just reporting to you what is actually happening in the real world.

1. Switch on your computer (Section 6.1).
2. If you need to, install the software (Section 6.2).
3. Start the program by entering the **AbaSim** directory and typing **ABASIM [Enter]** (Section 6.3).

Relax and enjoy it. Enter the simulated world!

Game 1 Gradual Development of a fishery

This exercise describes a situation where the fishery begins at a low level and steadily builds up. It is similar to the overall pattern of effort on most of Australia's abalone fisheries and particularly on the more accessible reefs.

1. Set the level of effort at **50** by pressing the up-arrow key **[↑]** once. Watch where the bar is on the Effort scale. It is at 50 hours per year.
2. Press **[Enter]** and watch what happens.
3. Press **[Enter]** again.
4. You have just applied 50 hours of fishing effort to AbaSim Reef over years 1 and 2.
5. You can reduce effort with the **[↓]** arrow key. Pressing the **[Shift]** key with the arrow keys allows fine adjustment.

The fishery has just begun. The first intrepid divers have put on their primitive wetsuits and ventured out from the boat ramp on a perfect, calm day late in summer. They stop at one of the first reefs they find and start looking for abalone, which they have heard can be sold at a nearby fish factory. Despite their lack of experience, their catch rates are fantastic and considering the low level of effort, the catch is good.

6. Catch rates, catches and effort are shown on the bottom graph on your screen.
   Catch rates **CPUE** are shown by the red line.
   Effort is shown by the blue dashed line.
   Catch is shown by the solid green area.
   The **Age** limit you are using (age 7 years) is shown by the broken yellow line.

Make sure you note the age structure of the catch now, as this may be useful in making future decisions. The age structure of the catch each year is shown at the top right corner of your screen where the different age classes are colour coded. Note that the older abalone are very important in the catch; abalone 15 years old and older make up most of the catch weight. You are fortunate that a biologist was waiting at the boat ramp to sample and age the catch to provide this information! This didn't happen in real life, and the technique for aging abalone wasn't discovered until about 25 years after the Australian abalone industry started.

Even though the divers almost have to give away their catch to the fish factory they do well enough to commit more of their time to diving for abalone. Other local divers hear about what's going on and join in.

7. Set effort at **100** and press **[Enter]** for **2** more years.
8. Increase the effort to **200** for **2** years after that.

   We record the sequence of controls you have entered up to now as:
   1(50 7) 2(.. .) 3(100 .) 4(... .) 5(200 .) 6(... .)

   A dot means that the value is the same as in the previous year.

Catches increase in proportion to the effort. Catch rates remain fantastic. In fact the catch rates are so stable that some inexperienced fishery biologists are convinced that the stock must be massive or at least extremely resilient. Advisers make some quick calculations and announce to the media that the local economy will be saved by this "liquid goldmine". People quit their jobs to collect abalone full-time. Amateur divers all over Australia plan to do likewise.

9. Increase the effort to **300** for the next **2** years and raise it to **400** for the **2** years after that:
   7(300 .) 8(... .) 9(400 .) 10(... .)

Catch rates (CPUE) start to decline a little indicating that the previously unfished stock has at last been dented. But they have only fallen about 10% so there doesn't seem any cause for concern. Most fishery biologists would expect CPUE to fall to about 30-50% of the virgin level before the stock is reduced to the level at which it will produce the maximum sustainable yield. However, if you have been watching the age composition of the catch you will have seen it change quite dramatically. The 7-8 year old abalone are now the most common age class. This suggests either that reproduction rates have increased greatly due to fishing down the old stock (the stock has become more productive) or the older abalone have been fished out.

Have you been watching the window in the top left hand corner of the screen? This is a diver's eye view of the reef, which covers the entire area of AbaSim Reef. The colour coding is the same as for the catch composition. The divers report that there are definitely fewer abalone now than before, but they can't be exact about how many.

You will also have noted that the divers only fish certain areas of the reef (only those cells are displayed). There are abalone on the rest of the reef. Things can't be too bad when the divers don't have to use the whole reef!

The existing divers must still be pretty happy about the stock because they are prepared to put more and more effort into the fishery. New divers also continue to enter the fishery. Should you do anything about the fishery? If you stop the industry growing now you might never know how productive it could be. Go ahead and see what happens. At least then you will know.

10. Set effort to **500** for **1** year.
    11(500 .)

What happened? Nothing much? CPUE continues its slight downward trend, just as you'd expect for a virgin stock being fished down to a productive level. Things seem to be settling down nice and gently. The 7-8 year olds are now twice as important in the catch as any other age group. Does this mean the fishery is becoming much more productive or is it just becoming more reliant on the newest recruits? Remember these recruits were born 7-8 years ago. The divers continue to tell you that the number of abalone on the reef is declining, which agrees with the CPUE data. So what are you going to do next year? Let the fishery continue growing.

11. Set effort to **600** and press **[Enter]**
    12(600 .)

Now you are on your own. Should the fishery be allowed to continue growing or should you take steps to control it? It's your decision. You know how to increase or reduce effort. You can also change the age limit by using the plus **[+]** and minus **[–]** keys.

If you crash the stock and don't wish to wait for it to recover, press **C** to **C**lear the simulation. Put the same initial scenario, shown over page as GAME 1, into the simulator and try again:

This time before you start playing do a couple of research surveys.

12. Using the **[←]** and **[→]** arrow keys you can move the time cursor backwards and forwards along the time line. Position the cursor under a year in which you would like to do a survey, press **'R'** (carry out a

Research survey). The model actually does the survey at the end of the year before the one you select. You can't do a survey in the first year.

An age and abundance profile of the stock will appear on the Biomass area in the middle of the screen. The colour code is the same as for the catch composition. Surveys of this standard are expensive to conduct. People who manage budgets don't like them. You shouldn't need more than two surveys before you start managing the fishery. Make sure you return the time cursor to the latest year (press **[End]**) before proceeding. With the benefit of the surveys, see if you can improve your management of the fishery.

Use the **[←], [→], [Home]** and **[End]** keys to move the time cursor to where you want to start fishing, change the control and press **[Enter]**. If you press the **[Shift]** key at the same time as an arrow key, the cursor moves ten years at a time instead of just one.

When you are ready, proceed to the second scenario.

Game 1 Gradual development of a fishery

In **E**ffort mode:
1(50 7) 2(.. .) 3(100 .) 4(... .) 5(200 .) 6(... .)
7(300 .) 8(... .) 9(400 .) 10(... .) 11(500 .) 12(600 .)

Game 2 Bonanza

The second scenario is typical of a reef that "gets discovered" in an established fishery. The reef has escaped the attention of the abalone divers for years. It has been so close to home that everyone assumed some one else would have discovered it by now, or the diving conditions are generally so bad that no one has bothered to have a good look at it, or it is so remote that improved technology has only just made it feasible for fishing. Whatever the reason, the fully developed fishery has finally caught up with this reef.

The word is out. Gold rush fever has hit the diving community. Everyone is sick of scratching around on their old tired patches. The runabouts are racing towards the new reef.

> Press the **'Q'** key to start a new scenario and switch the simulator into **Q**uota mode. In this mode you control the catch directly, but cannot control effort.
>
> Set the quota for this area of virgin reef at the maximum, **100** (tonnes/annum). Use the **[Enter]** key to make this catch for the first **4** years.
>
> 1(100 7)   2(... .)   3(... .)   4(... .)

Normally, the pressure on a 'new' reef would be expected to decline after a few years as the stock is reduced and divers go back to their home patches. However in this case we assume that quotas have been introduced into the other parts of the fishery and this reef is part of an area that has been left out of the quota system.

> Keep the catch at **100** until the 8th year.
> 5(100 7)   6(... .)   7(... .)   8(... .)

The divers say there has been a massive reduction in stock density. Did you watch the catch composition change? (**Note: The diagonal hatching** indicates that the height of the bar is slightly above the scale of the graph.) Catch rates have dropped about 40%, but they weren't very reliable last time were they? Are you going to be brave and manage the stock without surveys as real fishery managers often do? It's cheaper that way! Besides you can always do surveys next time. Maybe you should close the reef completely? But if you do that how will you know when to start fishing again? Surveys are good for this purpose. But a complete closure and surveys will be costly and make you unpopular. Maybe you should cut the catch savagely and risk the wrath of the

divers. You could always raise the age limit. Then again you could do what many others have done – nothing!

Try to manage the fishery from year 9 onwards. Experiment on your own.

You can **L**oad GAME 2 automatically by pressing **L**, using the arrow keys to select the scenario and pressing **[Enter]**.

When you've destroyed the stock to your satisfaction, proceed to the third and final scenario, where you will be told the secret of good fisheries management.

Game 2 Bonanza

In **Q**uota mode:

1(100 7) 2(... .) 3(... .) 4(... .)

5(... .) 6(... .) 7(... .) 8(... .)

. . . .

Game 3 Pulse Fishing

This scenario is similar to the situation at many of the more distant abalone reefs in Australia. Because of their remoteness they are not fished constantly, but experience periodic pulses of heavy fishing pressure. In some fishing zones, periodic closures are used as a management strategy: areas of reef are closed and opened periodically to the industry, the aim being to maintain high catch rates when divers do fish.

Switch the simulator back to **E**ffort Mode by pressing **E**.
Apply **800** (maximum) effort in year **1** and don't fish **(0)** for the next **2** years.
Apply **800** in year **4** and don't fish **(0)** in years **5** and **6**.
Repeat this pattern for years **7, 8** and **9**.
Reduce the intensity of the pulse in year **10** and only apply **600**.

Have you been watching the stock indicators? Catch rates have stepped down steadily and younger abalone now dominate the catch. However the divers' view of the reef hasn't changed much. What are you going to do now?

Are you going to accept the challenge and continue managing it with pulses of effort? Or are you going to try and force it to be a 'normal' fishery which is fished in every year?

Experiment on your own. Use the **[←]** and **[→]** keys to examine the age composition of the catch in several years.

After you've destroyed yet another abalone stock and are prepared to move on we'll let you into the secret of good fisheries management:

Game 3 Pulse fishing

In **E**ffort mode:

1(800 7) 2(0 .) 3(. .) 4(800 .) 5(0 .) 6(. .)
7(800 .) 8(0 .) 9(. .) 10(600 .)

Perfect knowledge of the stock
and
The ability to undo past mistakes

If you press **B** you will switch the computer model into **B**iomass mode. Pressing **B** a second time will switch this mode off. In **B**iomass mode the age structure and abundance of the abalone stock will be automatically displayed in the Biomass area in the middle of your screen. In the top left hand corner of your screen you will also be shown the distribution of the abalone over the entire reef, not just where the divers are diving. The **B**iomass mode can be turned on or off at any time so you can use it at the end of a scenario if you want to know what really happened.

You will also discover (if you have not already done so) that the model will allow you to re-write history. At any time you can move the time cursor along the time axis using the **[←]** and **[→]** arrow keys. This can be used not only to perform surveys at a certain point in time but to change management measures in retrospect. If you collapse the stock with a certain level of quota you can scroll back through time, put in a different strategy and then try again. You can do the same with age limits. Note that you cannot switch between quotas and effort control in the same scenario.

When you press **G** ('**G**o'), the model will continue the simulation using the management measures last used. Stop by pressing any key.

You can save games (i.e. "simulations" or "scenarios") by using the **S**ave command. You can replay them at a later date by using the **L**oad command.

You should now have all the skills necessary to operate the simulator. Concise operating instructions are presented in Chapter 6.

5 Lessons

In this chapter we discuss some aspects of the behaviour of the simulator. We believe they are worth noting for the insight they give us about abalone fisheries and the way they illustrate some of the basic concepts of fisheries management.

5.1 Abundance and catch rates

One of the first things you would have noticed was how unreliable catch rate CPUE is for telling you how much biomass you have left. There are specific simulations which illustrate this point.

1. Put the model into **E**ffort Mode and switch on the **B**iomass view. Set effort at **500** with a **7** year **Age** limit. Keep pressing **[Enter]** and watch the CPUE and the biomass. Before long you will see the biomass crashing. Note what CPUE is doing.

   It hardly changes! Watch how low biomass needs to fall before CPUE responds sharply. Note that when CPUE starts falling it does so catastrophically! If you haven't done something about the fishery before then, say goodbye to your career as a fishery manager.

2. Put the simulator in **Q**uota mode and switch on the **B**iomass view. Replay GAME 2 where the quota was set at 100 t/annum. Note how sharply CPUE and biomass are declining. Perhaps CPUE declines a little more slowly but on the whole you'd say it was showing you pretty well what was happening. After 8 years of this quota, reduce the quota by 50%. What do CPUE and biomass do now? CPUE increases sharply, while biomass keeps falling.

In this respect the simulator seems to reflect reality quite well. In the Mexican fishery extremely high catches of about 3,500-4,500 tonnes of abalone meat per annum were made through the 1950s, 60s and the early 70s. Effort was high but catch rates also remained high. In the late 1970s the catch collapsed and by the early 1980s it was about 10% of its virgin level. During this collapse catch rates declined rapidly, as did effort. After the collapse, when effort had declined, catch rates improved significantly. The total catch did not.

So the simulator confirms what abalone biologists have long known and which was reiterated at the First International Symposium on Abalone Biology,

Fisheries and Culture held in 1990 in Mexico. “Catch rates can be used as an index of abundance only when they are declining sharply. Stable or rising catch rates cannot be taken to indicate anything about stock abundance.”

The effect observed in the simulator is due to the aggregation of abalone and the ability of divers to target these aggregations. Catch rates decline because divers are catching them more quickly than the animals can aggregate. This is shown in GAME 2, where catch rates increase when quotas are reduced, even though the abundance of abalone continues to decline. Note that we are not necessarily saying abundance does not affect catch rates. What we are saying is that abundance is not the most important influence on catch rates.

5.2 Time lags

A feature shown by the simulator but which is less immediately evident is the time lag caused by the years taken between spawning and recruitment to the fishery. This can be most clearly seen if you go back to GAME 1 (page 18). Begin the first example again watching the **B**iomass. This time keep effort at **600** for years 13 to 17. Then set the effort to **0** and keep pressing **[Enter]**. You would think that the biomass would start rebuilding immediately. But it does not. Even without any fishing it keeps declining. The full effect of a declining biomass takes some time to work its way through the stock because it takes seven years for an abalone to grow to a size at which it becomes vulnerable to fishing.

This time lag can also work to the manager’s advantage. Play GAME 2 again. Compare it with the first exercise. Note how much easier it is to restore the stock to its full productivity. Interestingly, in this second exercise a similar tonnage is taken from the stock in a shorter time. You would expect this to cause greater damage to the stock than a similar tonnage over a longer time. The reason it does not is that there are still large numbers of immature animals in the stock when management is introduced.

The paradoxical effect of the time lag between spawning and recruitment may have been what saved the South African abalone fishery. In the space of about 7 years South Africa seemed to remove almost its the entire breeding stock. This resulted in a spectacular decline in the annual catch from approximately 3,000 tonnes in 1965, to less than 1,000 tonnes in 1970. In response, the authorities reduced the catch quota to 800 tonnes. You might think that this collapse signalled the end of the stock. But that was not the case: the fishery

has remained stable at 800 t/annum since 1971. It would seem that while the adult stock (animals 7+ years old) was severely depleted by the initial "over-exploitation", there were sufficient immature animals left to rebuild the stock after the introduction of proper management.

A different effect of the delay between spawning and recruitment can be seen if you play further with the third example. Pulse fishing can very easily generate a fluctuating population. If you watch the Biomass, you will see that fluctuations in the population are driven by previous fluctuations in spawning stock caused by periodic heavy fishing.

However if you did not have the benefit of seeing the biomass and were dependent on surveys, you would have difficulty distinguishing between pulses of recruitment generated 7 years before and genuine stock recovery resulting from more recent changes to management.

The importance of timing to management can also be shown in other ways. It is possible to create scenarios where delaying the implementation of a management policy by one year means the difference between collapsing a stock and rebuilding it. Try it.

The crucial element in all this is the time between the spawning of a year class and its recruitment to the fishery – the "generation time". Because abalone have a relatively long generation time abalone stocks do not collapse suddenly. They just decline slowly. This may offer comfort to managers of abalone fisheries, but the disadvantage is that a recovery will also take a long time.

5.3 Size (Age) Limits

The simulator also shows some of the advantages and limitations of managing the fishery by imposing size limits. Where there is very little knowledge, size limits can be introduced to the fishery as a conservation measure that is easy to apply.

If stock conservation is your only concern, an abalone fishery can be managed with size limits alone. No controls on effort or catch are necessary.

But did you try managing the population with size limits and leaving the quota or effort control extremely high? You would have noticed that the divers are the ones who suffer, for catch rates plummet with that type of management. So if you are interested in the *economics* of your fishery, direct controls on catch or effort are more efficient methods of controlling exploitation.

At this point we should highlight a difference between this simulation model and the real world. While the principles noted above are applicable to the real world, the use of size limits in abalone fisheries is in fact far more complex than this model suggests. In the real world, fishery managers must manage a large number of reefs as a single fishery. Unfortunately the growth and breeding characteristics of abalone usually vary considerably between reefs. Populations with the best growth rates will be the least protected by any particular size limit (Appendix B.10). The impact of this is that a single size limit is likely to over-protect the areas least needing protection and concentrate effort on the areas most susceptible to over-exploitation. It would be possible to use different size limits to protect each of the populations, but the data requirements and enforcement problems would most likely be prohibitive.

5.4 Quotas

The simulator highlights some interesting limitations of management by using quotas. Probably the most significant is the damage that can be caused by having an inappropriately large quota. It is very easy to collapse the stock with quotas. This is because there is no control on effort; no matter how scarce the abalone become, the divers continue working to fill their quota.

Controlling effort would be more effective because the number of abalone declines and falling catch rates make further fishing less attractive.

5.5 Research surveys

AbaSim demonstrates the value of research surveys, especially at the start of a fishery.

If you do not have any estimates of the age structure of the population (i.e. Biomass on the screen) and rely solely on the catch and effort information presented in the bottom graphs, your chances of managing the fishery well are slim.

6 Operation

6.1 Computer hardware required

To run **AbaSim** you need a computer compatible with an IBM-PC with a 286 chip (e.g. IBM AT, 386Sx, 386, 486 etc.) and a colour VGA screen.

The software will run much faster if you use a maths coprocessor.

6.2 Installing the program

AbaSim is supplied on a 720kB (3.5'' or 5.25'') diskette.

To install AbaSim onto a hard disk, insert the supplied diskette into an external diskette drive and type **A:INSTALL [Enter]** (or **B:INSTALL**).

An installation program will run. When it asks, type the name of the directory into which the programs will be loaded. (**C:\ABASIM** is offered as a default.)

(You can also run the program directly off a diskette by logging the diskette drive as the default directory.)

6.3 Starting and stopping the program

1 Enter the **AbaSim** subdirectory. (e.g. Type C:> **CD ABASIM [Enter]**)

2 Type: **ABASIM [Enter]**

3 Stop the program by pressing **[Esc]**.

6.4 The main screen

The **AbaSim** screen displays the following information:

Screen area	Variable displayed	Location on screen
Reef map	Abalone spatial distribution by age category.	Top left
Catch	Catch weight by age category. Definition of age categories.	Top right
Biomass	Abalone population biomass by (coloured) age category.	Middle
Outcomes (and) Controls	Catch, CPUE Effort, Age limit.	Bottom

A vertical white cursor ('time cursor') showing the "Point in time" being viewed can be moved left and right by using the arrow keys. The catch histogram shows the catch weight by age category from the previous year's fishing.

Standard colour code

Colours used to code Age Categories can be seen at the top right of the screen.

(If you are not using a standard VGA screen configuration, the colours listed below may be different. Refer to the on-screen colour codes.)

Colour	Age Category
Dark blue	3-4 years
Blue	5-6
Light green	7-8
Green	9-10
Yellow	11-12
Orange	13-14
Red	15+

Colour	Outcome or control	Units
Green shaded area	Catch	tonnes
Yellow dashed line	Age at first capture	years
Blue dashed line	Effort	hours fished per year
Red line	CPUE (Catch Per Unit Effort)	kilograms per hour

6.5 Keyboard control

You can see a list of these on the computer screen at any time by pressing **H** for **H**elp (or **[F1]**).

Fishing	
[Enter]	Advance one year
G	**G**o, advance till interrupt
Controls	
[↑], [↓]	Adjust effort/quota
[Shift ↑], [Shift ↓]	Fine-adjust effort/quota
[+], [–]	Adjust age limit
Movement	
[→], [←]	Move cursor forward or backward 1 year
[Shift →] or **[Shift ←]**	Move cursor forward or backward 10 years
[Home]	Cursor to start year
[End]	Cursor to end year
Quit	
[Esc]	Stop **AbaSim**
Mode	
E	Switch to **E**ffort mode
Q	Switch to **Q**uota mode
C	**C**lear game
View	
B	**B**iomass switch on/off
R	**R**esearch survey
A	**A**bout screen
H	**H**elp screen
Files	
L	**L**oad game from disk
S	**S**ave game to disk
P	**P**rint screen to HP Paintjet printer

6.6 Saving and loading scenarios (games)

You can store scenarios as computer files by using the **S**ave command.

When you type **S** the screen prompts you to enter the name of a file in which to store the game currently being displayed on the screen.

Type in a name of fewer than eight characters and press **[Enter]**.

You can **L**oad simulations that were previously stored by typing **L**.

You will be offered a list of existing files. Use the arrow keys and **[PgDn]** and **[PgUp]** keys to highlight the file you want to retrieve and press **[Enter]**.

The scenario you want will be loaded.

AbaSim is supplied with three scenarios already loaded. They are the games you played in Chapter 4 (i.e. **GAME-1, GAME-2** and **GAME-3**).

All files are saved to and retrieved from the same directory as that from which the **AbaSim** program was run.

Appendix A Ordering the software, service

AbaSim is available in single copies or as site licences.

Please contact us if you develop and document useful scenarios.

Your comments and suggestions are most welcome.

Contact:
FISH INSIGHT

South Australian Department of Fisheries
135 Pirie Street, Adelaide, South Australia.

Postal address:
GPO Box 1625, Adelaide, SA 5001, Australia.
Telephone: 08) 226 0633
International ...61) 8) 226 0633
Facsimile: 08) 226 0664
International ...61) 8) 226 0664

Appendix B Details of the models

B.1 The simulation model only keeps track of 15 year classes, but the oldest year class is actually an accumulation of even older year classes which are assumed to have the same body weight and mortality rates.

B.2 This gives the average probability that an abalone of any age will survive until the next year. The table is based on southern Tasmania data and some conjecture. Annual survival is assumed to increase from approximately 30% in the youngest age class to 90% in the oldest age classes.

B.3 In the model it is assumed that the amount of food in any cell will depend on the number of abalone in that cell. A cell with many abalone will have less food than one with fewer abalone. When there is a high number of abalone in a cell, up to 24% of the abalone in that cell will move in one of the four cardinal directions out of the cell during each year. Of course some abalone in the surrounding cells will also be moving into the cell, so that the net effect may not be so great.

The directional movement of abalone has been observed by some scientists to be dependent on the size (or age) of the abalone. However, for simplicity, it is assumed that on AbaSim Reef only the mature animals move and that amongst these animals, movement doesn't depend on either age or size.

B.4 To achieve this the model assumes that no more than 24% of abalone move from any one cell towards a shallower cell each year, regardless of the number of abalone in that cell. Only sideways or downwards movements vary with the number of abalone in the cell.

B.5 This may seem strange, but it is possible that at high densities large abalone will interfere with small abalone, and the smaller abalone will suffer. At high densities the crevices under the rocks may become too full and small abalone may be pushed out to where they become more vulnerable to fish, crabs or starfish, or to large abalone (which may accidentally smother, crush or even eat them).

It should be remembered that on AbaSim Reef, density and movement of adults interact. This interaction has been adjusted so that adults will only keep aggregating while their density is less than the best density for breeding. At densities of 1.5 – 2.0 abalone per square metre, which is the best density for breeding, movement towards deeper water will be the same as towards shallow water. Thus there will be no tendency to aggregate at these densities; instead, they will start expanding the area in which they aggregate. If this didn't happen the abalone population could collapse itself by all abalone crowding into the shallow area and ruining their chance of breeding success. It is possible that some similar mechanism exists in nature, but this has yet to be proved.

Above a certain age, the number of eggs produced by each mature abalone is more or less proportional to its body weight. So the simulation model uses the total weight of mature abalone in each cell to calculate the number of one-year olds produced.

Food supplies may also limit the size of a population.

B.6 On AbaSim Reef the level of recruitment within each 100 x 100 m cell is determined by the density of the breeding stock in the cell and is independent of the surrounding cells.

B.7 In this respect the real world is considerably more complex than the simulated world. In the real world divers have many reefs to choose from. These reefs will vary in depth and diving conditions, and in the abundance and accessibility of the abalone. Generally the deepest, most inaccessible reefs with the worst diving conditions will have the greatest abundance of abalone and potentially the highest catch rates. So how a diver chooses between reefs will have a large effect on catch rates. The diver's choice will be largely determined by how desperately he or she wants to maximise catch rates. So in the real world, catch rates may be determined by many things besides the size of the stock.

To take the diver's choice into account, the model reduces catch rates in the shallow area to 15-30 kg per hour less than the catch rate possible in deeper water. This difference in fishing pressure and catch rate is maintained through the program.

B.8 That is, an average abalone diver would take one hour to find all the legal-sized abalone in an area of 34 x 34 metres.

B.9 All these factors can be put together into an equation to calculate a catch rate for any density of abalone:

$$\text{CPUE} = (d \times P) / (1 + h \times d \times P).$$

CPUE stands for Catch Per Unit Effort (catch rate), d is the density of abalone in numbers per square metre, P is the fishing power of the divers in square metres effectively swept per hour, and h is the handling time required to capture each abalone.

B.10 Abalone that grow slowly have more opportunities to spawn before they become vulnerable to fishing than do fast growers. Since fast growers are also more likely to offer profitable fishing, they are more at risk from overfishing.

Appendix C Further reading

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